

## Information Pamphlet 12

# GROUNDWATER/SURFACE-WATER STUDY IN THE BOULDER VALLEY: EFFECTS OF GROUNDWATER WITHDRAWAL

Andrew Bobst and Ginette Abdo

*Ground Water Investigations Program, Montana Bureau of Mines and Geology*

The Montana Bureau of Mines and Geology (MBMG) conducted a groundwater/surface-water study in the Boulder Valley, Jefferson County, Montana to address the effects of groundwater withdrawal for new residential development and its potential to decrease stream flows in the Boulder River. The study also evaluated the potential of infiltration basins to increase late-summer stream flows.

Groundwater development in near-stream shallow aquifers depends on aquifer properties and the distance between the well and the stream, and has a direct effect on stream flows. For this study the most intense development modeled, 128 residences on 10-acre lots, would cause flow in the river to decrease by 0.06 cubic feet per second (cfs) after 20 yr of pumping. Stream flows would continue to decrease until all of the pumping was offset by the stream.

This study also showed that local hydrogeologic conditions do provide the opportunity to use managed recharge to enhance stream flow. Model simulations of infiltrating water into the bench sediments showed an increase in late-summer flows by up to 2 cfs. The effectiveness of using infiltration basins to increase stream flows depends on the location and size of the infiltration basins, and on the underlying soil and aquifer properties.

## BACKGROUND

The Montana Department of Fish Wildlife and Parks has classified the Boulder River as "chronically dewatered," and portions of the river often go dry in the late summer. As such, the lower Jefferson Watershed Council and Jefferson County nominated the Boulder Valley for an investigation that focused on the effects of additional groundwater development to stream flows.

From 2011 to 2013 the MBMG's Ground Water Investigation Program (GWIP) monitored water levels in 78 wells, measured stream flow at 17 surface-water stations, and conducted 13 aquifer tests (fig. 1). The MBMG also collected water-quality samples from 34 wells and 15 surface-water stations. These data were used to develop groundwater flow models.



Figure 1. Canal flows were measured so that canal leakage rates could be calculated. Canal leakage is an important source of groundwater recharge in the Boulder River Valley.



## HYDROGEOLOGIC SETTING

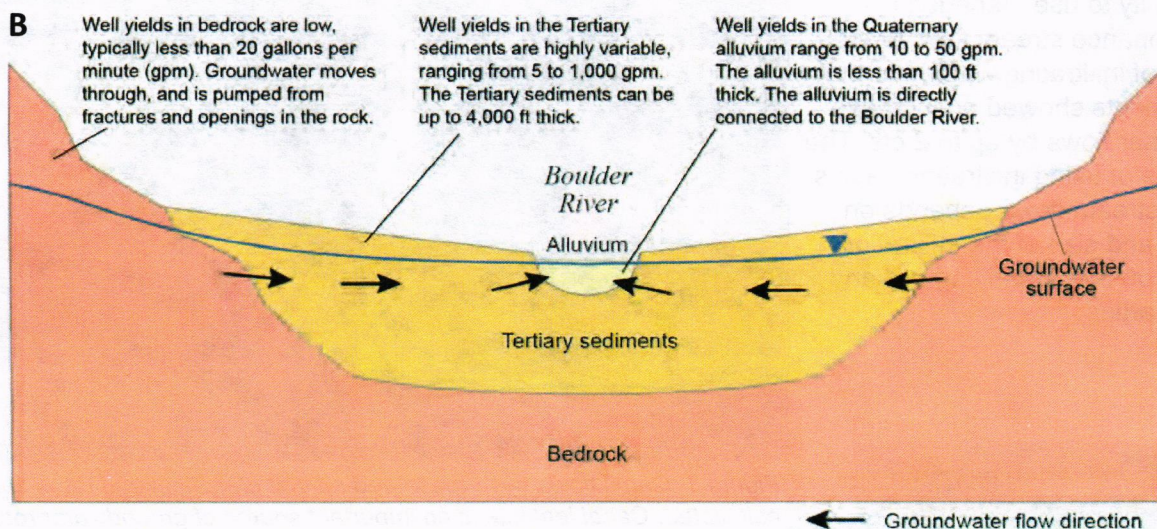
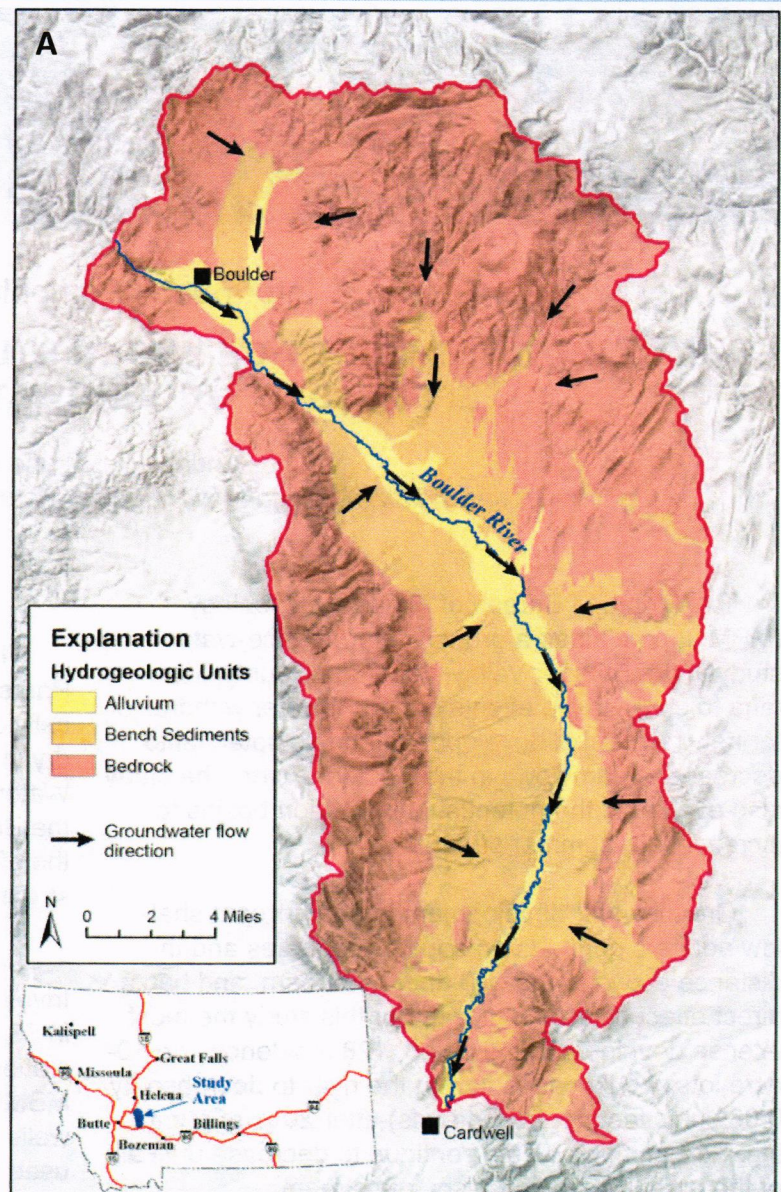
The geologic formations in the study area were grouped into three units based on their hydrogeologic properties (fig. 2):

1. consolidated bedrock,
2. semi-consolidated Tertiary sediments, and
3. unconsolidated Quaternary alluvium.

Although the hydrogeologic units have different aquifer properties, they readily exchange water with each other.

In areas unaffected by irrigation, groundwater levels peak during snowmelt. In irrigated areas, groundwater levels peak during the irrigation season due to recharge from canal leakage and excess water applied to fields. Near the Boulder River, groundwater levels respond to changes in river levels.

Figure 2. There are three main hydrogeologic units in the boulder valley: the bedrock, Tertiary sediments, and Quaternary alluvium. (A) The bedrock units underlie the valley and outcrop in mountainous areas. Tertiary sediments lie on top of the bedrock. Quaternary alluvium was deposited on top of the Tertiary sediments within the modern Boulder River floodplain. (B) Groundwater flows through the aquifer system from the mountainous areas towards the Boulder River.





## GROUNDWATER/SURFACE-WATER INTERACTION

Streams that gain flow from groundwater are called gaining streams (fig. 3A). Streams that lose flow to groundwater are losing streams (fig. 3B). Some portions of a stream may be gaining while others are losing. At a particular location a stream can transition between gaining and losing depending on how stream and groundwater elevations change over time. For example, during high flows water may move from the stream to the groundwater, but during low flows water may flow from groundwater to the stream.

The Boulder River changes between gaining and losing in the study area (fig. 4). The greatest gains in stream flow occur above areas where the alluvial aquifer constricts, becoming thin and narrow, which causes groundwater to discharge to the river. Below these constrictions, where the alluvial aquifer becomes wider and deeper, water flows from the river into the aquifer (losing).

Because groundwater and surface water interact, pumping groundwater can cause decreases in stream flow. When streams are gaining, pumping will cause

a reduction in groundwater discharge to the stream. When streams are losing, pumping will cause stream losses to increase. In either case, unless there is some additional source of water, stream flow will be reduced by the volume of water pumped over the long term.

## WATER QUALITY

The groundwater in the study area is generally good for drinking; however, some standards were exceeded. Four sampled wells had arsenic concentrations exceeding the 10  $\mu\text{g/L}$  human health standard; the source of the arsenic was not determined. Two wells exceeded the human health standard for nitrate (10  $\text{mg/L}$ ). Elevated nitrate values often result from septic systems or feed lots, but a source determination was not made in this investigation.

The Boulder River water is also generally of good quality; however, four samples exceeded the human health standard for arsenic (10  $\mu\text{g/L}$ ). The Montana Department of Environmental Quality has identified mining and milling as the probable sources of arsenic in the Boulder River. Natural sources of arsenic are also present within and upstream of the study area.

## GROUNDWATER BUDGET

Groundwater budgets are used to aid in understanding the components of groundwater recharge and discharge, and their relative importance. In the Boulder Valley, recharge to the aquifer system comes from canal leakage (46%), infiltration in the uplands (35%), and water that infiltrates from irrigated fields (19%). Groundwater leaves the aquifer system through discharges to the Boulder River (76%), evapotranspiration from riparian plants (15%), and consumptive use from pumping wells (8%).

## GROUNDWATER AND SURFACE-WATER IMPACTS FROM INCREASED RESIDENTIAL DEVELOPMENT

Since at least the 1940s, hydrogeologists have recognized that pumping water from shallow aquifers will affect stream flows. This reduction in stream flow is known as stream depletion. In the long term, the amount of stream depletion will equal the amount of water removed from the aquifer. The magnitude and timing of stream depletion will depend on how well the aquifer can transmit and store water, and on the distance between the pumping well and the stream.

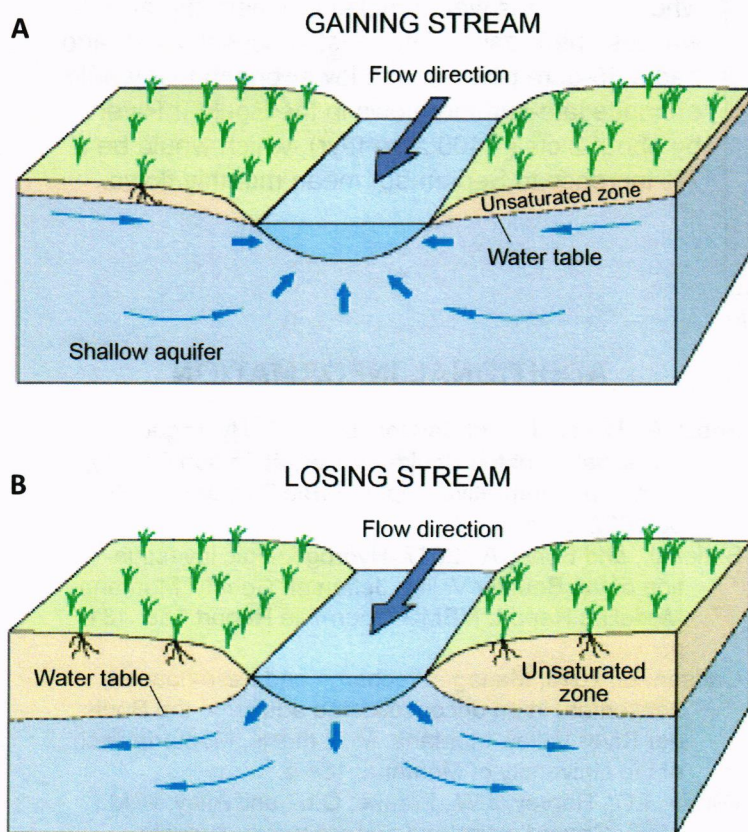


Figure 3. Streams may gain water from the groundwater system (A), or lose water to it (B) (modified from Winter and others, 1999).



## USING MANAGED RECHARGE TO ENHANCE LATE-SUMMER STREAM FLOW

Managed recharge is intentionally adding water to an aquifer for subsequent recovery or environmental benefit. In the Boulder Valley, the MBMG evaluated the potential to use infiltration basins in the spring to increase flows in the Boulder River during the late summer. For this process to be successful, a useful quantity of water needs to recharge the aquifer, and flow back to the river at the right time of year. The permeability of the materials underlying the basins will determine the amount of recharge. The timing of discharge to the river will depend on the degree to which the aquifer will transmit and store the water, and the distance between the basins and the river.

The MBMG used a groundwater-flow model to assess the potential to divert water in spring to infiltration basins on the Tertiary bench sediments above the Boulder River to supplement late-summer flows. The potential benefits of infiltrating the water were evaluated by varying the location and size of the basins. Less water could be recharged when the basins were smaller or where the aquifer was less permeable. The most successful scenario had a 35-acre basin on the lower bench that would enhance late-summer flows in the Boulder River by about 2 cfs (1,400 acre-ft/yr), which would be a 7% increase in September mean monthly flows.

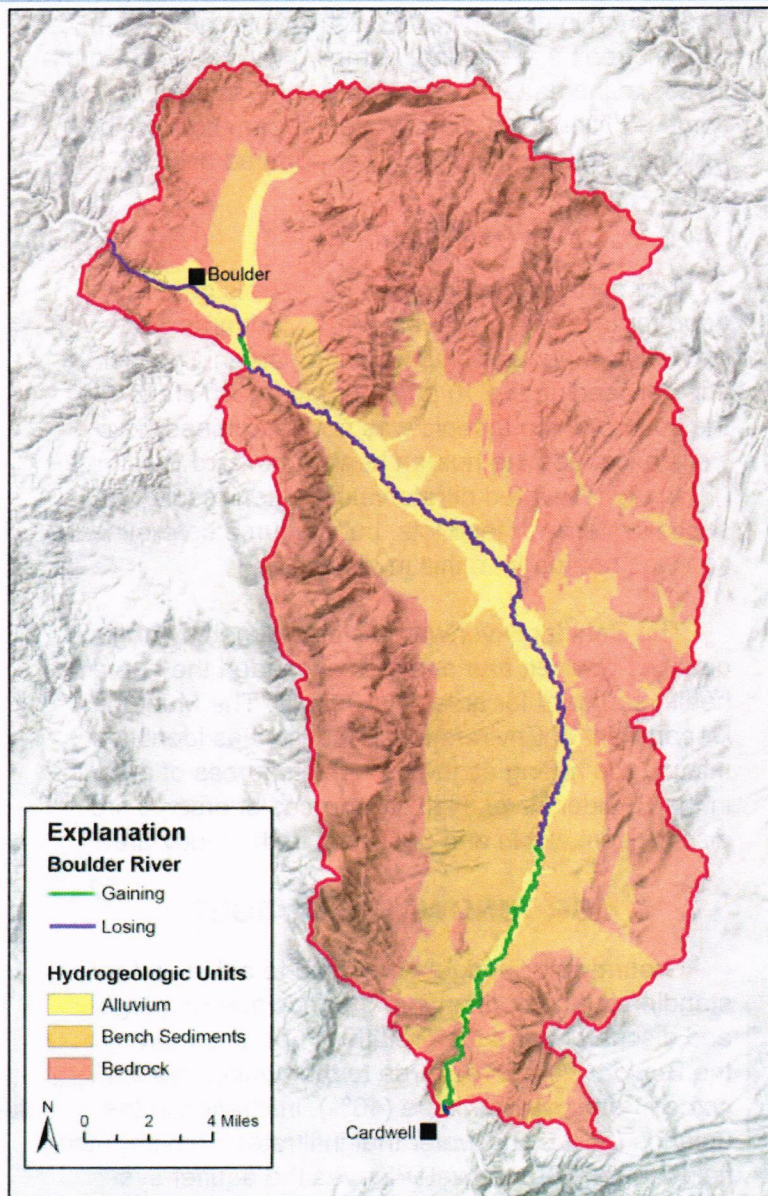


Figure 4. The Boulder River changes between gaining and losing in the study area.

The MBMG developed a groundwater flow model for the Boulder Valley based on the water budget, monitoring data, aquifer tests, and distribution of the hydrogeologic units. The model evaluated four subdivision scenarios by simulating 58 to 128 residences on 10- or 20-acre lots. The most intense modeled development [128 residences on 10-acre lots, for a combined average pumping rate of 38.7 gpm (0.09 cfs)] caused modeled Boulder River flows to decrease by 0.06 cfs after 20 yr. The amount of stream depletion increased over time for all scenarios. When pumping was adjacent to streams, depletion reached 84% of the pumping rate after 20 yr; when pumping was at least 1.2 mi from streams, the depletion reached 64% of the pumping rate. In all scenarios it is anticipated that the depletion will eventually be equal to the pumping rate.

## ADDITIONAL INFORMATION

- Bobst, A., Butler, J., and Carlson, L., 2016, Hydrogeologic investigation of the Boulder Valley, Jefferson County, Montana: Interpretive Report: MBMG Open-File Report 682, 92 p.
- Butler, J., and Bobst, A., 2017, Hydrogeologic investigation of the Boulder Valley, Jefferson County, Montana: Modeling Report: MBMG Open-File Report 688, 131 p.
- Carlson, L., 2013, Managed recharge and base-flow enhancement in an unconsolidated aquifer in the Boulder River Valley, Montana: M.S. thesis, Montana Tech of the University of Montana, 164 p.
- Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M., 1999, Ground water and surface water: A single resource: United States Geological Survey Circular 1139, 79 p.